DE LA RECHERCHE À L'INDUSTRIE

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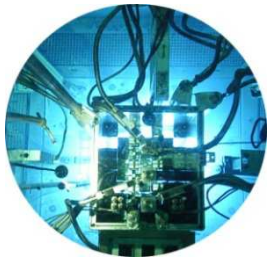
SYNERGIES BETWEEN NUCLEAR AND RENEWABLE ENERGY SOURCES: FRENCH CONTEXT AND THE CEA EXPERIENCE




Françoise TOUBOUL
Hervé BERNARD
CEA France

Golden, June 9th, 2016

SINCE 1945, ATOMIC ENERGY COMMISSION

SINCE 2010, ATOMIC AND ALTERNATIVES ENERGIES COMMISSION

European TOP R&D organization for energy

World TOP public organization for innovation

V. Masson-Delmotte, GIEC

Physical sciences, software, Climate high performance computing, biomedicine

Fontenay-aux-Roses

Saclay

Bruyères-le-Châtel

Valduc

Le Ripault

Materials

Micro-Nanotechnologies
Nanobiotechnologies
New technologies for energy

Grenoble

Nuclear :
Nuclear fuel cycle and waste management

Marcoule

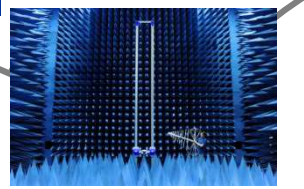
Cadarache

Cesta

Gramat

Lasers & plasmas

Nuclear :
Fusion, fission
Bioenergies, solar



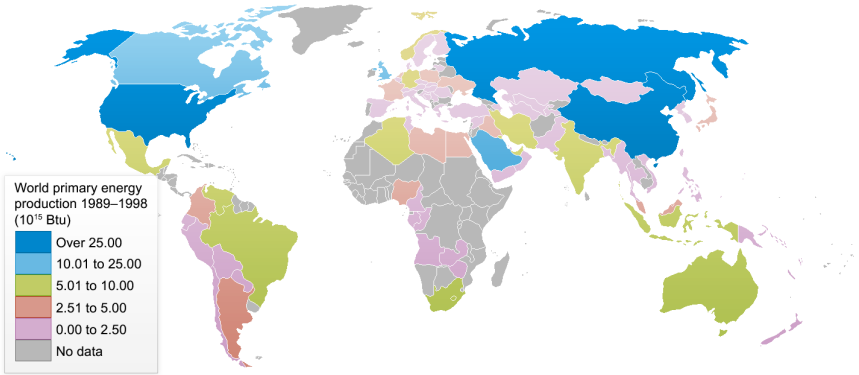
Vulnerability assessment
Detonics

ENERGY IS A MAJOR ISSUE

« This crisis is not financial, but energetic »
Jeremy Rifkin, american essay writer, prospectivist, 2013,

« The time of energy is a lengthy time »
Daniel Yergin, historian, energy specialist, 2013

« The issue of energy transition is far beyond national borders »
Peter Altmaier, German energy minister, 2012



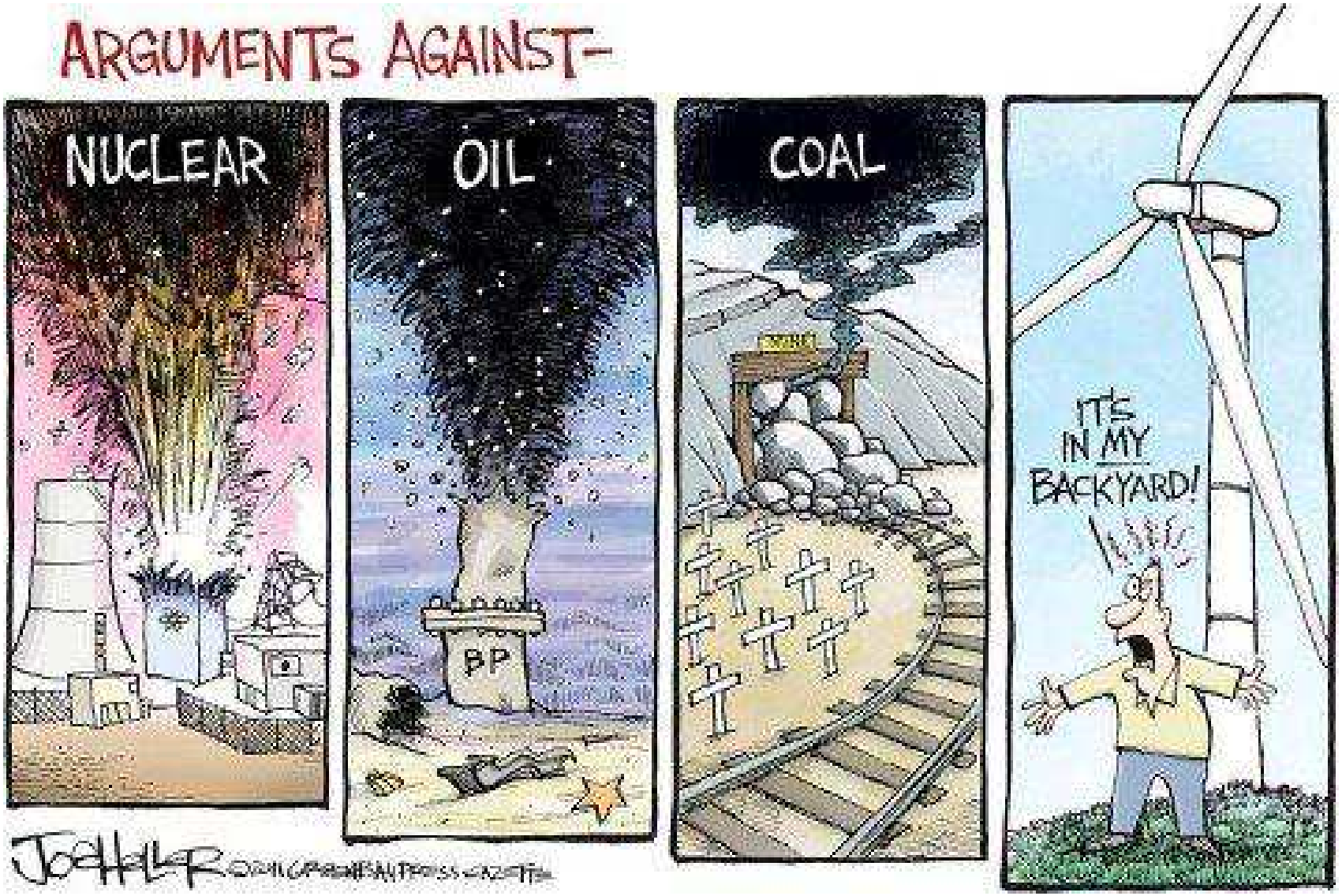
CO_2 free ENERGIES

NUCLEAR

RENEWABLE

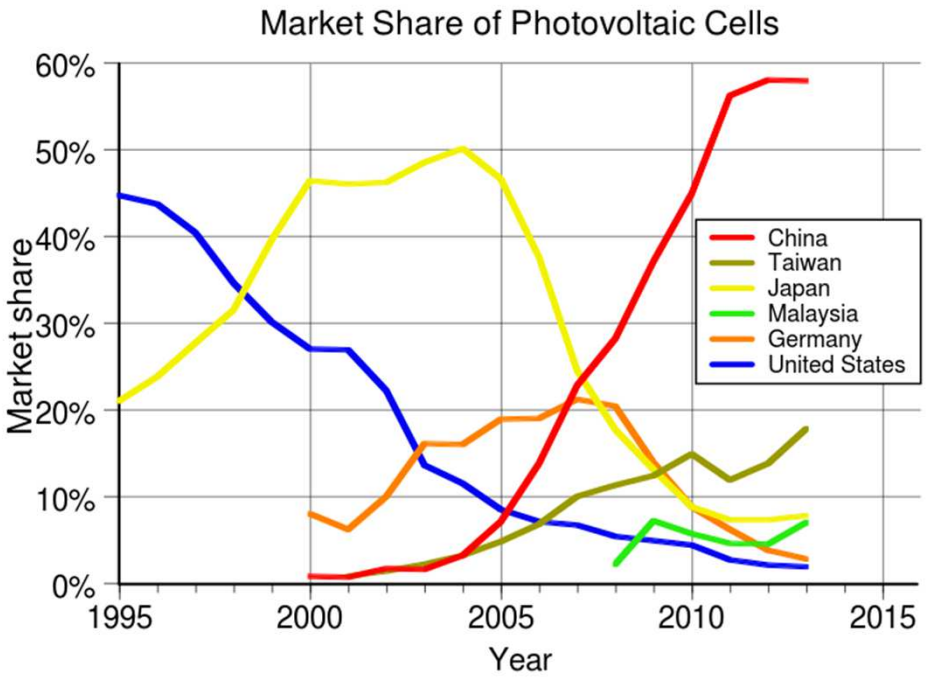
Cumulative emissions of CO2 largely determine global mean surface warming by the late 21st century and beyond. Projections of greenhouse gas emissions vary over a wide range, depending on both socioeconomic development and climate policy. *GIEC - 2014*

ENERGY IS A CONTREVERSIAL ISSUE

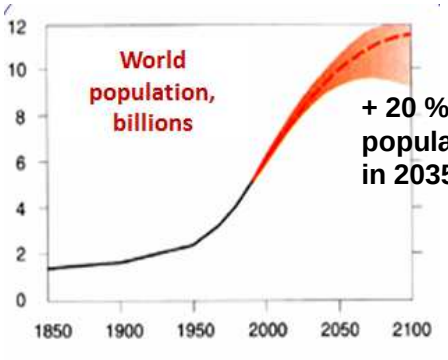


ENERGY IS A CONTREVERSIAL ISSUE

SOLAR

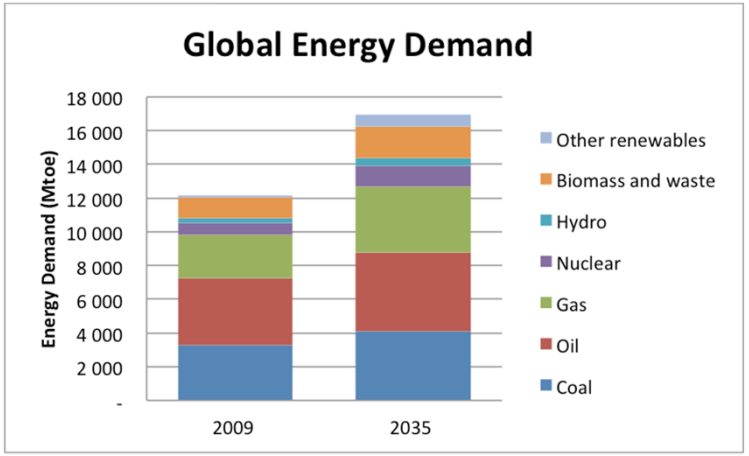


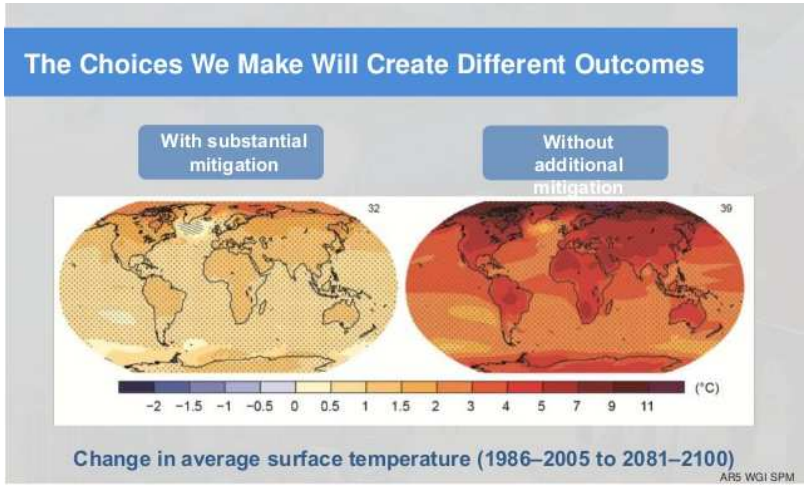
GLOBAL ENERGY CONTEXT



+ 20 % world population increase in 2035

- Even when promoting « green economy » and « energy savings », **energy needs will continue to grow**
- 2.5 toe / year as a minimum need for everybody would represent: **+ 40 % energy demand in 2035**



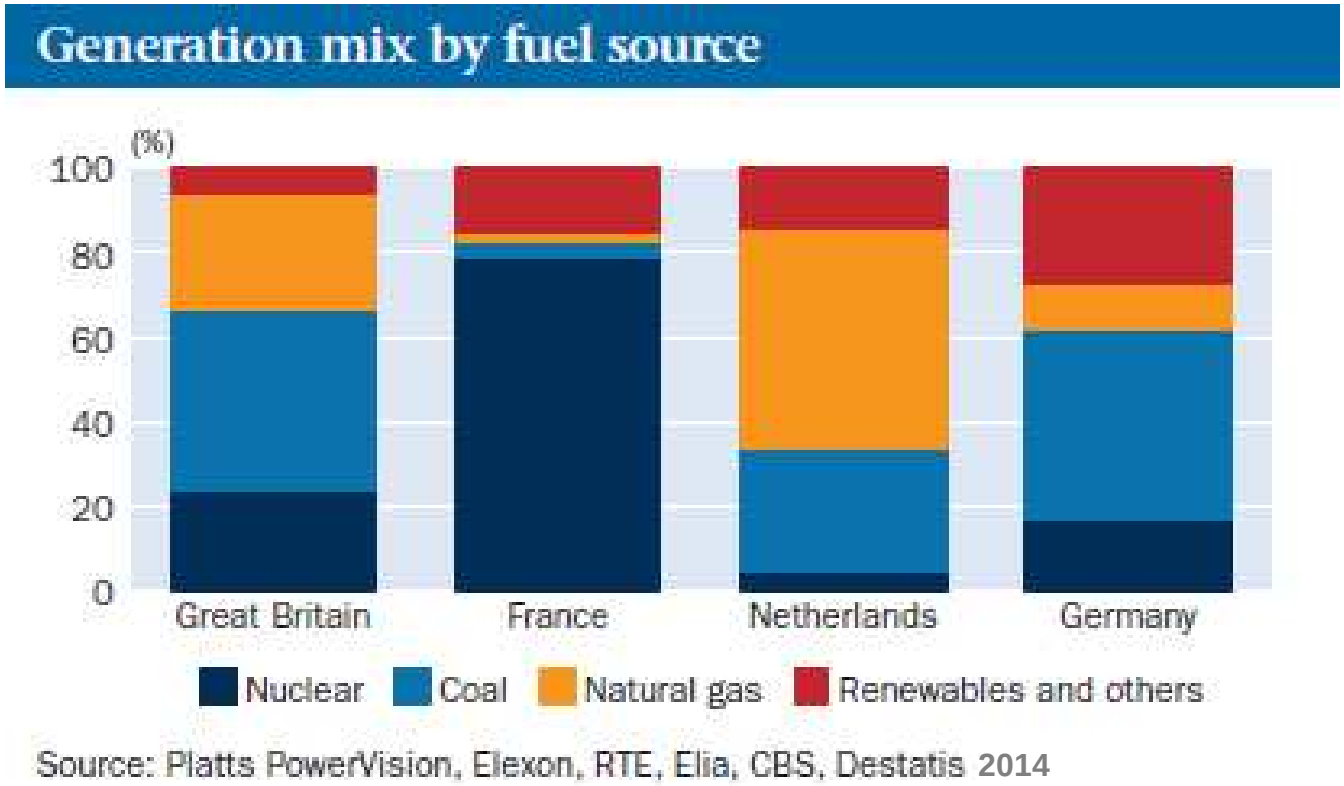


GIEC WG1 2015 report

Global warming:

- a drastic reduction of **GHG** is necessary
- a drastic reduction of **fossile energy** is necessary

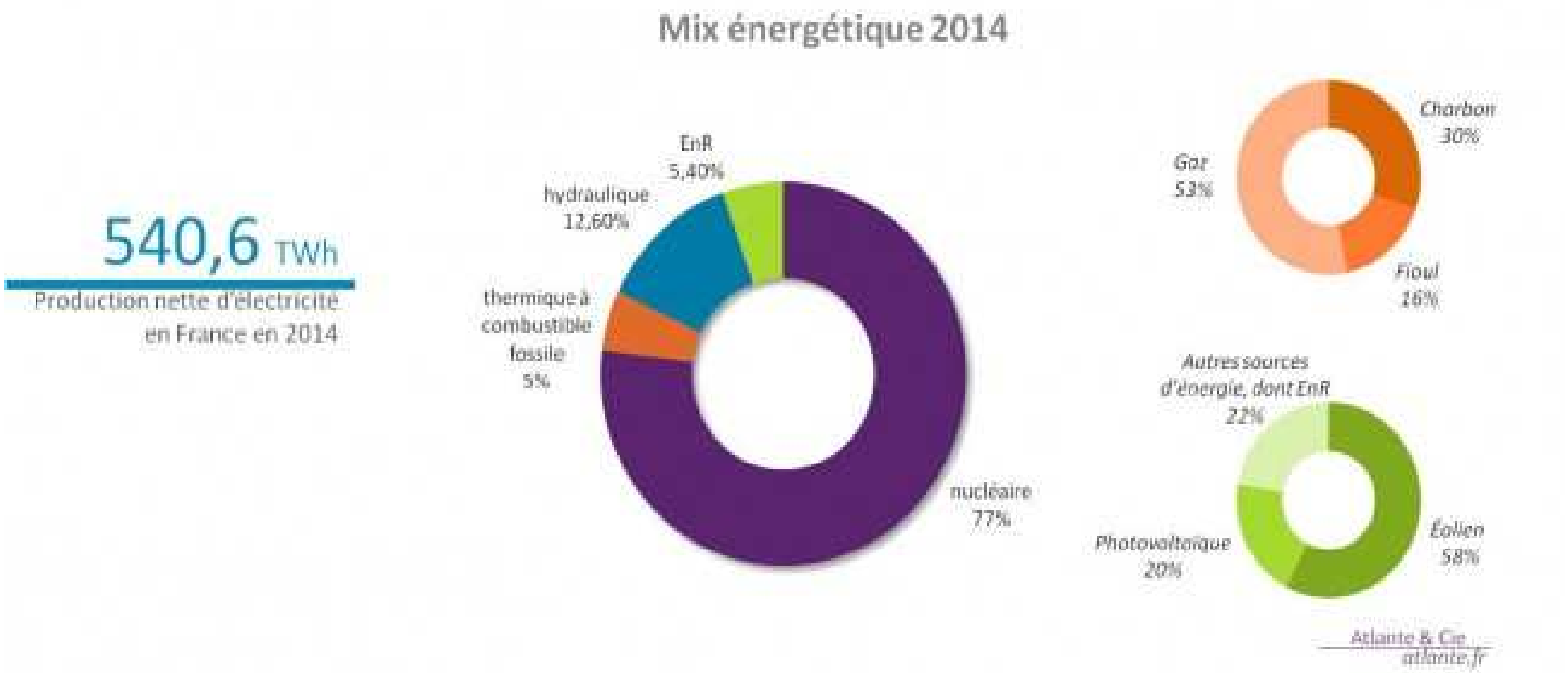
THE EUROPEAN POWER MIX



Source: Platts PowerVision, Elexon, RTE, Elia, CBS, Destatis 2014

THE FRENCH POWER MIX

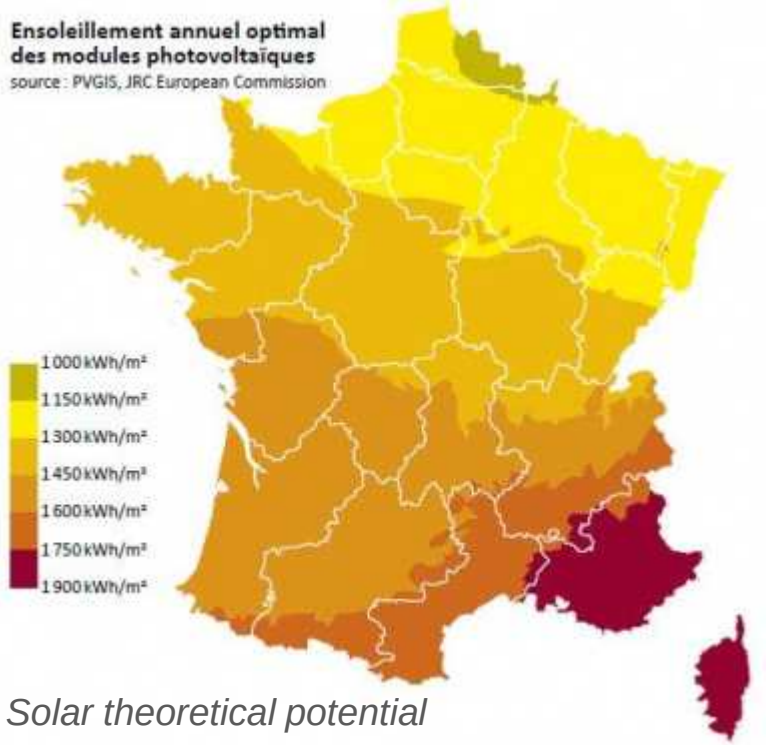
- the significant role of nuclear



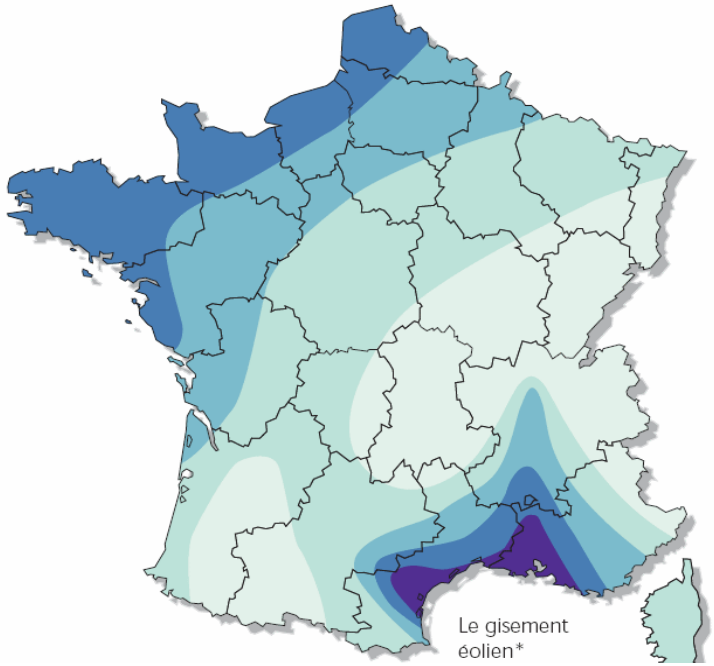
French electric production (%)

Source: RTE, 2014

RENEWABLE ENERGIES SPECIFICITIES



Solar theoretical potential



Potential for wind energy

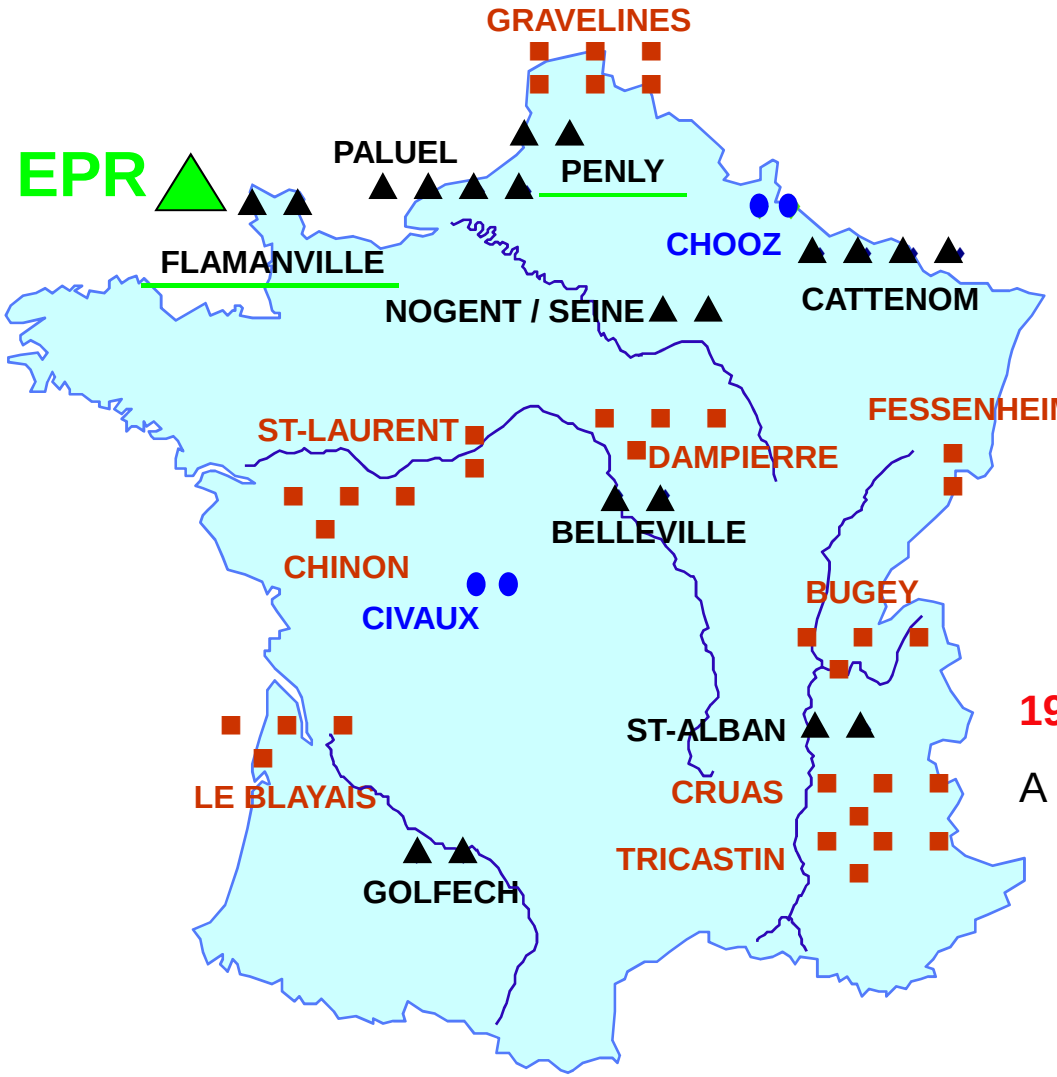
Very low greenhouse gas emission
Preservation of natural resources
proximity of producer and consumer

But :

intermittent energy sources
difficult to predict
a regional disparity

Need for R&D, Need for back up

A SIGNIFICANT SHARE OF NUCLEAR IN THE FRENCH ENERGY BALANCE



63,2 GWe installed

58 PWR units

*In 2018, **59** units*

900 MWe	1300 MWe	1500 MWe
34	20	4
■	▲	●

19 sites ; **1** single technology

A fleet :

- Young : average age **= 29** years old
- Mature : **> 1250** cumulated reactor-years

EUROPEAN R&D COORDINATION IN EERA

European Energy Research Alliance

- A **public research alliance**
- Chaired par Hervé Bernard from **CEA**
- A cornerstone of the Strategic Energy Technology Plan **(SET-Plan)**
- Bringing together **170 research organizations**
- Working together in **17 Joint Programs**
- Collaborating with European **Industry**
- With a global outreach
- **And aligning national research**

JPs launched in 2010

Bioenergy	≈ 327*
CCS	≈ 361*
Geothermal	≈ 408*
Mat. For Nucl.	≈ 198*
Wind Energy	≈ 162*
Smart Grids	≈ 144*
PV	≈ 162*

JPs launched in 2011

AMPEA	≈ 522*
CSP	≈ 132*
Energy Storage	≈ 430*
FC&H2	≈ 160*
Ocean Energy	≈ 45*
Smart Cities	≈ 212*

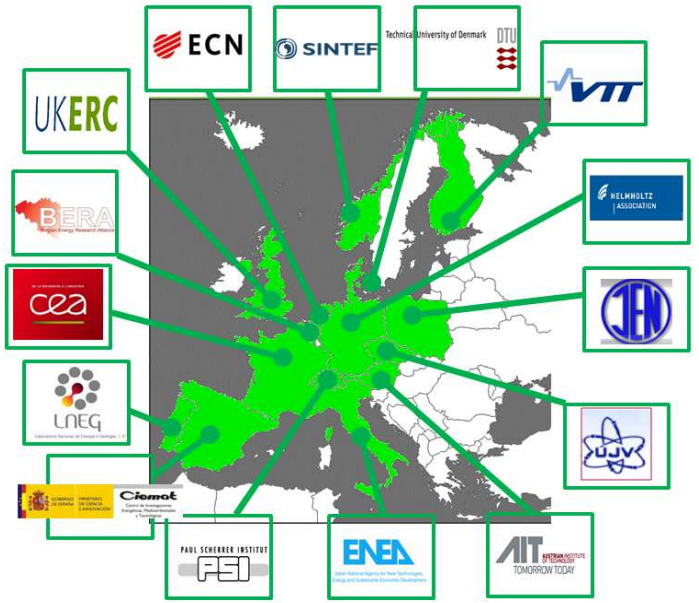
JPs launched in 2013

Environmental, economic and social impact "E3S"	≈ 194*
Shale gas	≈ 181*

JPs Launched in 2015

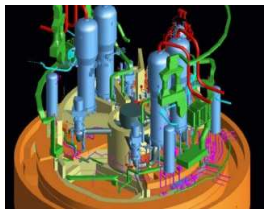
- Energy Efficiency in Industrial Processes
- Energy Systems Integration

*FTEs (Full-time equivalent)



EUROPEAN R&D IN SUPPORT TO THE DECARBONISATION OF ENERGY MIX

Some basic principles



Technology Neutrality

- All kinds of energy sources
- Competitiveness of European industries

Opening to partnerships

- Structured partnerships with industries
- Joint funding : private, public, European : about 15 to 20 G€ since 2013 for Europe

Complementarities

- Nuclear – Renewable
- Grid management
- Green H_2
- Low temperature heating

FRENCH R&D COORDINATION IN ENERGY IN ANCRE

FRENCH NATIONAL ALLIANCE FOR ENERGY RESEARCH COORDINATION : UNIVERSITIES AND NRO

- **Produce 4 Scenarios on French energy mix**
  - maximum sobriety
  - Diversified vectors
  - Priority use of electricity
  - High nuclear power

- **Social Breakthroughs**
  - Every scenario assumes significant changes in behavior
  - Massive deployment of new technologies need to be investigated at the economic and societal levels

- **Economical aspects**

  the costs are very high (order of magnitude of 1 trillion € of investment) but the benefits in the medium-long term can be very significant as larger than this trillion (over 40 years)

EUROPEAN ENERGY POLICY

European energy supply relies at 80% on fossil fuels today

Mainly imported from a limited number of countries

Increasing financial burden

Threat for health, environment and climate

European Climate and Energy Package sets 2014 climate and energy targets for 2030

Reduction by 27% of the overall consumption of primary energy

Reduction by 40% Of greenhouse gases emissions *(compared to 1990)*

With a 27% share of renewable energy In the energy mix

FRENCH ENERGY TRANSITION LAW

Quantified targets

Reduction by 50% of the overall consumption of primary Energy in 2050

Reduction by 40% of GHG emission in 2030 and 75% in 2050

Reduction by 30% of fossil fuel in 2030

With a 32% share of renewable energy In the energy mix In 2030

Efficiency / Sobriety

Nuclear and renewable

The two pillars of the French energy mix:

- **Variable Renewables**
- **Nuclear energy:**
  - **50% of the electricity production by 2025**
  - **production maintained at its current level: 63,2 GW**

FRENCH ENERGY TRANSITION & GREEN GROWTH BILL

FIVE CLEAR AND VOLUNTARY OBJECTIVES

- **to reduce greenhouse gas emissions** to contribute to the European objective of lowering these emissions by **40% by 2030** (compared to the 1990 reference) and even further to **divide it by 4 by 2050**;
- to **reduce our consumption of fossil fuels by 30% by 2030**;
- to **reduce the nuclear share to 50% of the electricity production by 2025**;
- to shift the **share of renewable energies to 32% of our end energy consumption by 2030**, or 40% of the electricity produced, 38% of the heat consumed and 15% of the fuels used;
- to **divide our end consumption of energy in two by 2050**.

THREE PILLARS

- **The energy savings,** in housing, transport and by developing circular economy
- **The development of renewable energy resources,**
- **Simplification, regulation, strategies**

→ SNBC
PPE
SNRE

http://www.gouvernement.fr/en/energy-transition-towards-green-growth

MAIN POINTS OF FRENCH ENERGY TRANSITION LAW

Accelerate energy generation from renewable sources.

Accelerate the energy renovation of buildings (homes, public buildings, the tertiary and industrial sectors).

Incorporate a section on the "circular economy" into the energy transition bill, encourage recycling.

Develop industries for the future within the framework of industrial projects: to revitalise industries related to energy transition: electric aircraft, the TGV (high-speed train) of the future, cars that can run for 100 kilometres on 2litres of fuel, electricity recharge points, biofuels, plants of the future, etc

Implement the environmental transition component of the future investment programme – 2.3 billion euros- and develop the**"Sustainable cities" projects** and positive energy territories.

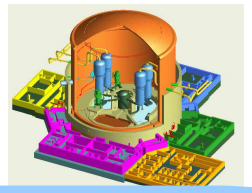
FRENCH SCENARIO FOR A SUSTAINABLE NUCLEAR ENERGY

Renewable energies deployment

1970 1990 2010 2030 2050 2100

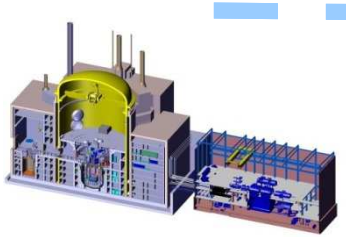
Generation I

Generation II, reactor life extension



Generation III deployment EPR™

ASTRID (Demo.) Generation IV



Fusion

ITER

CEA MISSION

CEA is a Governmental organization with the following missions:

- Produce the key elements of France deterrence policy; ensure strategic stocks of nuclear materials; contribute to non proliferation issues
- Develop expertise and innovation allowing France to benefit from a safe, durable and economically competitive nuclear electricity
- Since 2005, develop R&D for renewables especially in the domains stemming from its research on nuclear energy
- Develop fundamental, applied and technological research supporting those missions
- As a result actively participate to the reindustrialization of the country.
- 54% of 1,6B€ direct costs expenditure dedicated to Energy

- Represents France at the IAEA
- Main Shareholder of AREVA

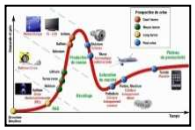
CEA : ATOMIC AND ALTERNATIVES ENERGIES COMMISSION

CEA R&D IN SUPPORT TO THE DECARBONISATION OF ENERGY MIX

Control the impact on environment

Climate

Strategic raw material resources



Technico-economy

Technology by 2020-2030

Electricity production

Centralised nuclear production

Localised PV and CSP production

Indirect storage

Demand/ response Management

Demand/response Adaptation

2G Batteries

Electrolysis Hydrogen 2G biofuels

Smart grids

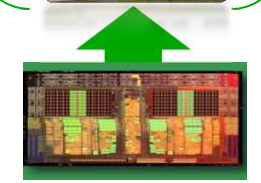
Building, cities, regions, country

New applications

Electric and hybride vehicle

Industry

Building



Green IT

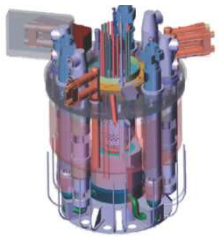
Efficiency/sobriety

Unused energy

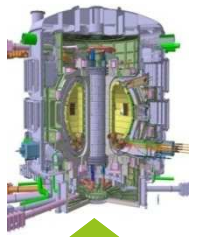
> 2040- 2050

Energy storage

4th Generation

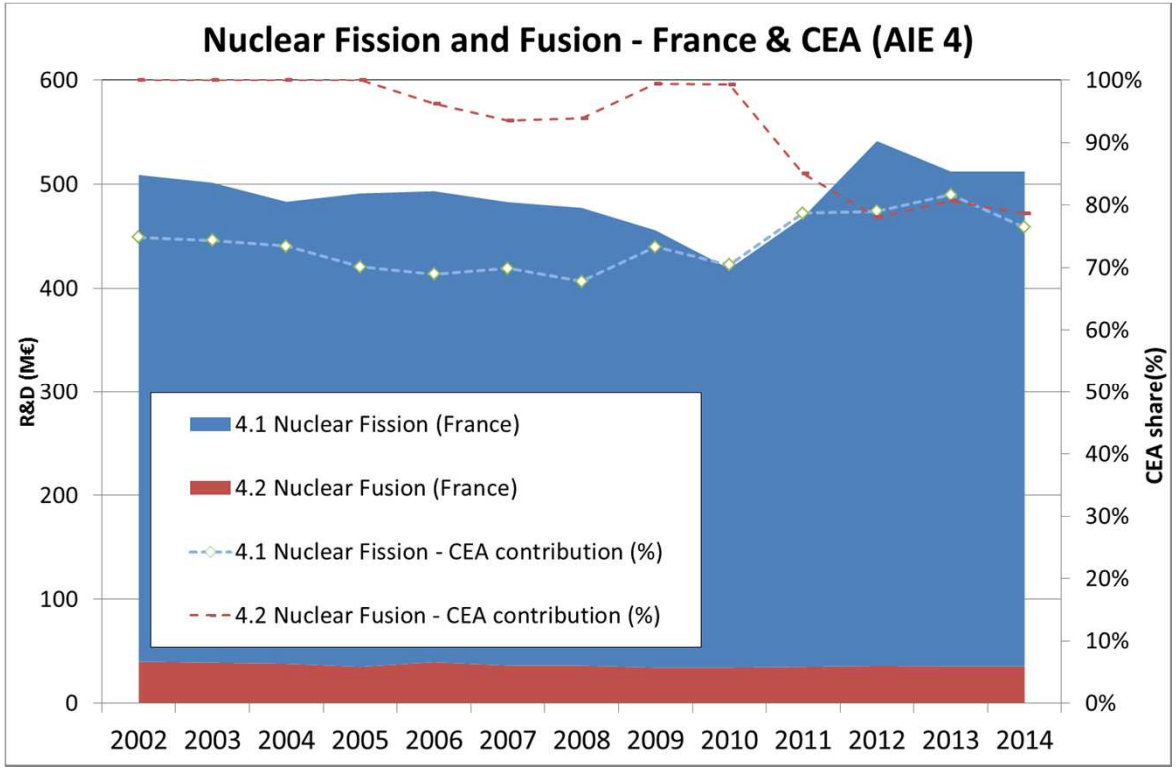


Nuclear fusion



Basic research in energy

NUCLEAR ENERGY FUNDING



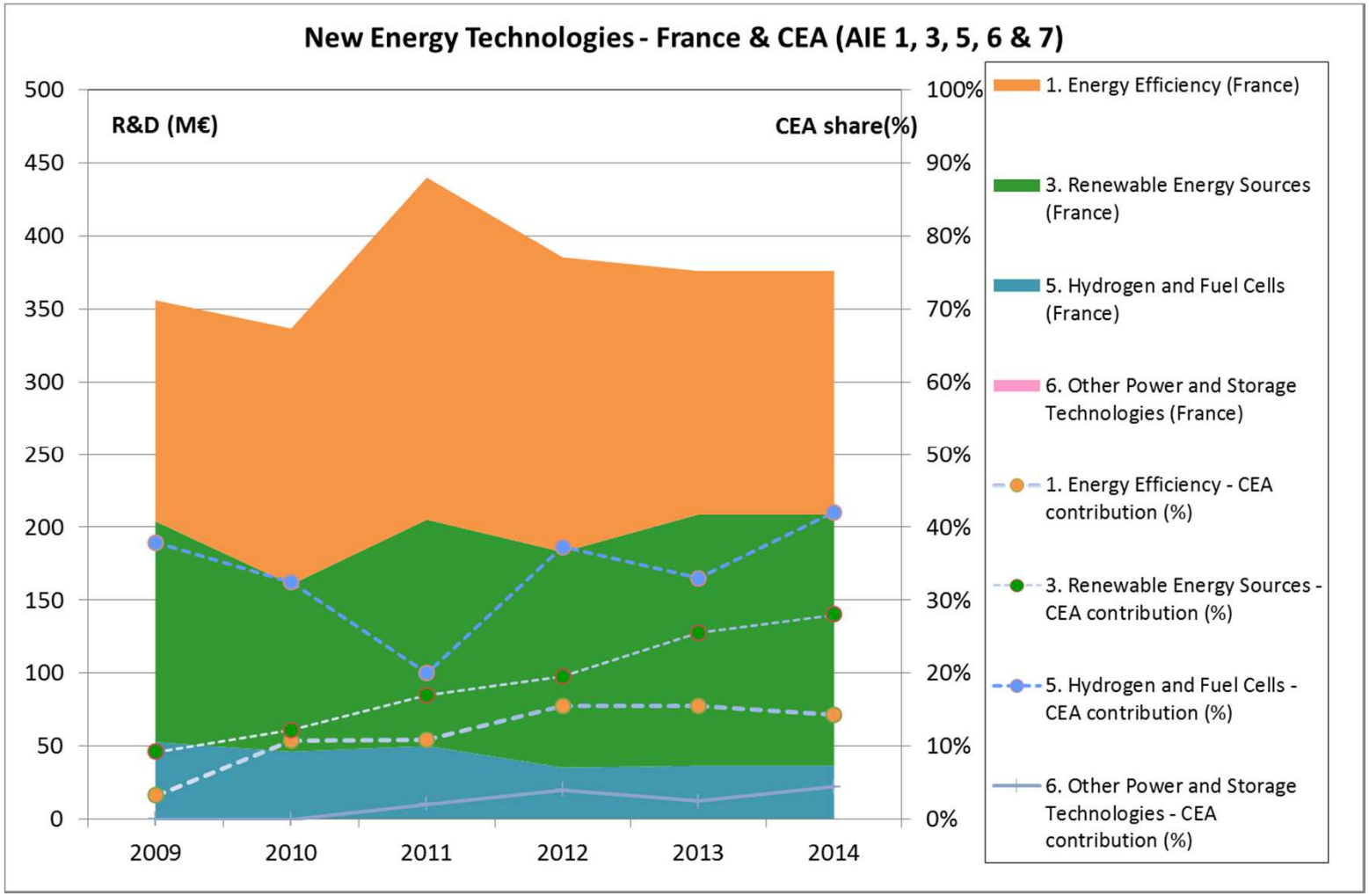
National R&D declared to IAE and CEA share of national spending

CEA Nuclear R&D programs :

govt funding 2015 : 61%

external funding including industry 2015 : 39%

RENEWABLE ENERGIES FUNDING



R&D declared to IAE and share of national spending

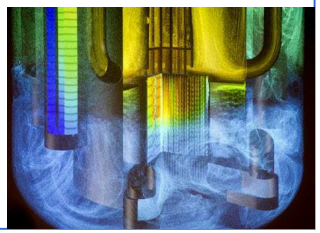
CEA COMPLEMENTARITY OF ENERGY PRODUCTION SYSTEMS

Renewables

- Solar
- Wind and tidal energy
- Biofuels : 2nd and 3rd Generation (microalgae)

Nuclear

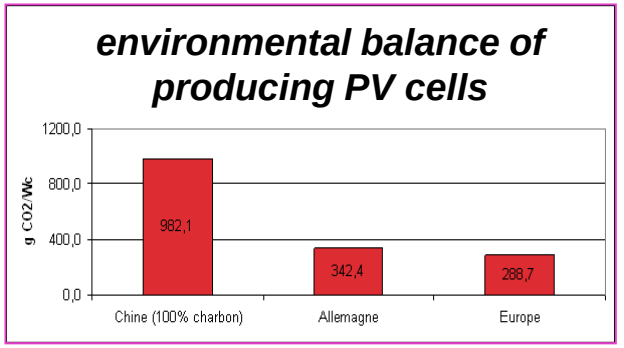
- Safety and competitiveness of Gen 2 and 3 reactors
- Developing Gen 4 reactors : highest safety standards, better use of uranium
- Sustainability of nuclear energy : geological disposal of ultimate wastes
- Research infrastructures : Material Testing Reactors, critical assemblies, hot labs, fuel fabrication facilities
- Simulation, High Performance Computing centers



Nuclear + Renewables => system approach

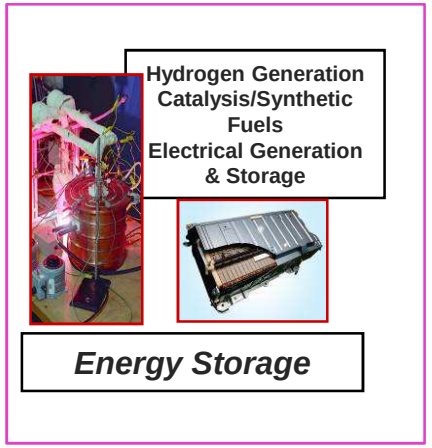
CEA energy program expenses : NUC ~ REN

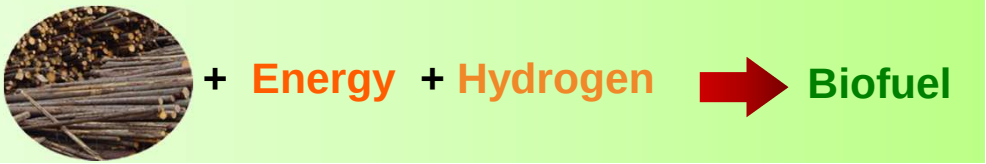
WELCOME SYNERGIES BETWEEN NUCLEAR AND REN



Following examples pave the way to closer synergy development :

- A nuclear base allows the development of **PV cells "Carbon free"**
- The production of **"green" hydrogen** (nuclear or REN) enables the production of Biomass-to-liquid valuing 100% of the carbon in biomass
- Association of a NPP with electrolyzers is an advanced instrument to **compensate the intermittency of REN**.





ENERGY PRODUCTION : SYSTEM APPROACH

The power system reliability is essential to ensure for the short term and long term :

- For the long term: adequacy between the installed capacity and peak demand
- For the short term: real-time balancing

A need for back-up

Nuclear: a possible option to help renewables integration into the power mix

A need for nuclear energy flexibility

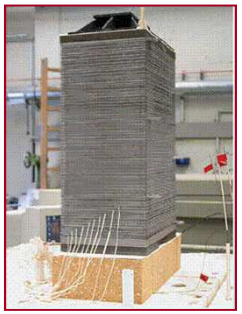
NUCLEAR ENERGY FLEXIBILITY

- **Nuclear modulation is already achieved, but could be more even more effective**, especially in the case of country with large production facilities since production variation could be reached only by small increments in each power plant.
- This would remain true as long as installed nuclear power is large enough, in terms of contribution to the global electricity mix.
- In economic terms, gas back-up is generally more competitive than nuclear but a carbon-tax could change the trends, which advocates for incentives to avoid the effective greenhouse gas release.
- Nuclear back-up is all the more competitive than amortized power plants are utilized.
- SMR can help flexibility

INNOVATIVE APPLICATIONS OF NUCLEAR ENERGY : HYDROGEN PRODUCTION

alkaline electrolysis

H_2



High température electolysis

BIOMASS + HYDROGEN → BIOFUEL

$C_6H_9O_4$ + water + 5.5 H_2 → 6 -CH_2- & CO

Transports Distribution storage

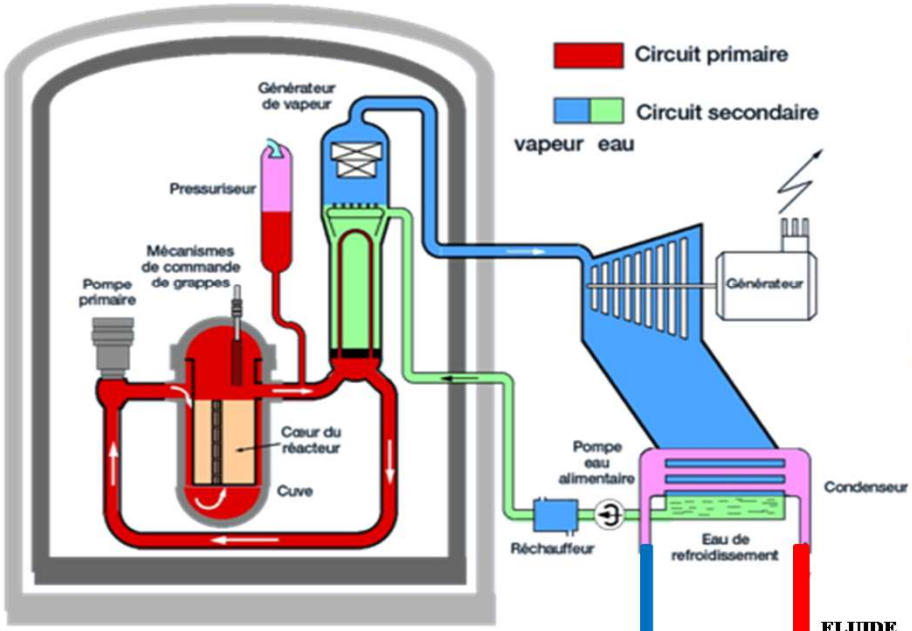
2e génération biofuels

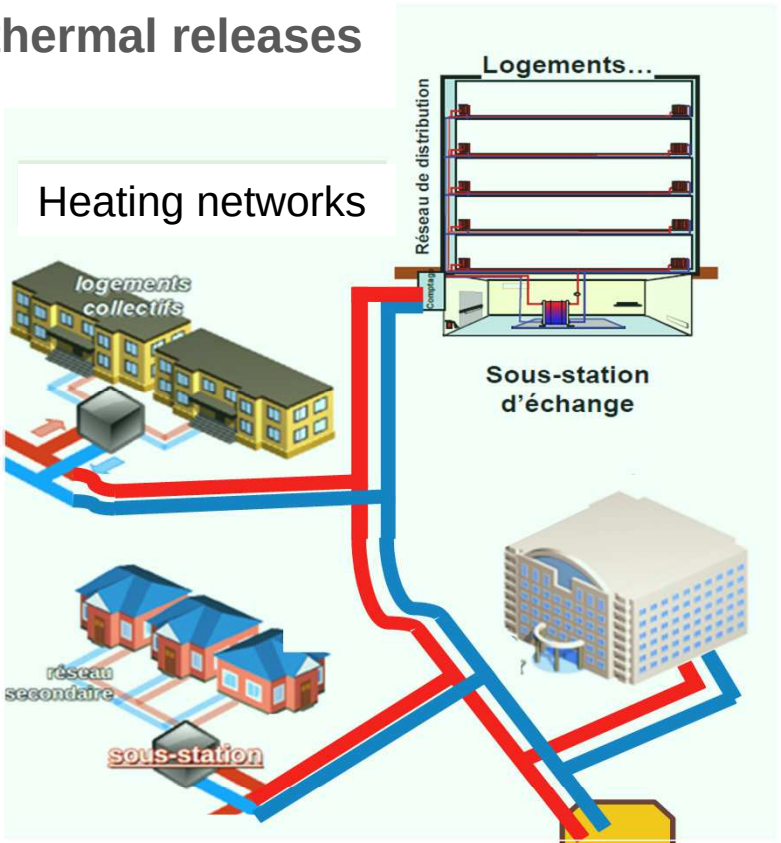
Industrial Applications (NH_3, refining, chemicals…)

Transports

NUCLEAR CO GENERATION

Urban heating from nuclear power plants thermal releases





Transport lines

62 miles

CONCLUSION

A sustainable energy supply is a major challenge for all countries

Joint efforts must be as high as the stake

There are different possible national energy mixes

- No single way to decarbonisation
- All CO2 free energy production type are usefull
- A solution is a joint development of renewable energies and nuclear

<u>Increased R & D effort</u> is essential to reach the decarbonisation objectives :

- To leave open several options
- To take advantages of complementarities

CONCLUSION

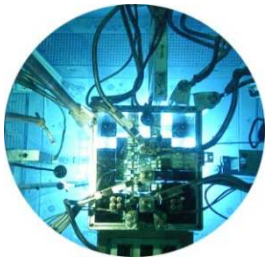
In spite of the recent Fukushima accident, the use of nuclear energy still remains a need for many countries. Nuclear has the potential to contribute even more by the Gen IV technologies in the future

Safety is of course an absolute priority. It relies in particular on continuous improvement taking into account operational feedback and the results of R&D

R & D on renewable energy will focus on removing technological and economical barriers that hinder the use of renewable energies

Nuclear and renewable energies are more than ever complementary. In the future, nuclear energy, with a controlled and continuously improved security, and renewables will contribute, in synergy, to the global energy mix

R&D and international cooperations are keys for an optimal energy future in the world : sustainability and competitiveness



Thank you for your attention

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